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Ex-Vivo Tribological Behavior of Cow Skin

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Abstract

Friction involving human skin considers one of important role in daily human life. There are several tried to measure the friction in the human skin in the reality, but it's still difficult due to limited the equipment. In the current study, the cow skin is used to measure the coefficient of friction as a function of angular velocity and different pressure. Moreover, Parameters such as contact area and the tip of indenter depth was measured in the study. The study results showed that the coefficient of friction is decreased when the pressure increased, whereas it's increased when the angular velocity increased.

Keywords: Friction skin; twist friction; ex-vivo skin; cow skin.

1. Introduction

The mechanical behavior of cow skin considers nonlinear and viscoelastic properties. A search of the literature revealed few studies which have compared the differences in the mechanical properties of skin when tested in vivo and ex vivo. In addition, no research has been conducting to study the friction of cow skin. Mattei and Zahouani1 [1] carried out a number of investigations on the human skin adhesive behavior at different parameters; the normal load, the indentation speed, the contact time and the indenter geometry under controlled experimental conditions by using different theory. Results showed that Hertz theory gives good results for normal skin but cannot be applied to treated skin; moreover, the Hertz theory is unsuitable to correctly evaluate skin mechanical properties.

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In the same objective, Zhang and Mak [2] studied the effect of normal and untreated skin over six anatomic regions of ten normal subjects under a controlled environment on in vivo frictional properties of human skin and five materials, namely aluminum, nylon, silicone, cotton sock and Polite. The average coefficient of friction for all measurements is 0.46±0.15 for all materials. The study results showed that the hand has the highest coefficient of friction, related to the material the silicone has the highest coefficient of friction, whereas the nylon has the lowest friction compared to the other materials. Hurtado and his colleagues [3] carried out a number of investigations into the tribological performance of Lorica, Silicone Skin L7350 and Epidermal Skin Equivalent by analyses the interaction of three artificial and human skins against the main material components of artificial turf and compared to ex vivo human skin. It has been noted that the Silicone Skin L7350 showed significant differences, whereas the Lorica and ESE samples have similar performance of when compared to the ex-vivo skin. To determine the properly materials and develop a new moisture-sensitive Artificial Skin Model (ASM), Nachman and Franklin [4] compared the human volar forearm of a healthy 29-year-old with various synthetic materials. It has been reported that the friction behavior under dry and moist environmental conditions was shown to be very similar to that of human skin.

Kuassy and his colleagues [5] proposed a model to measure the hysteresis component of friction between the human skin (Voight material) and the rigid sphere at different friction parameters (load, velocity, the strength of the interface between skin and the artificial material). The deformation (hysteresis) component of the skin friction model is developed by used Mathcad software. The numerical studied shown that the adhesive component of the skin friction is greater than the hysteresis component at all operating conditions. A recent systematic literature review concluded that the data are scattered over a wide range that can be understood based on the adhesion friction model. While the friction of dry skin is characterized by relatively low and pressure-independent friction coefficients [6].

Boyer G. and his colleagues [7] investigated viscoelastic properties of human skin, such as dynamic indentation, topography, spring constant (stiffness) and damping. The acquired outcomes showed that human skin behaves as a viscoelastic material and surely could be described by the Kelvin-Voight mechanical model under dynamic load (indentation), in other words, such features are being governed by the natural tensile condition of the human skin.

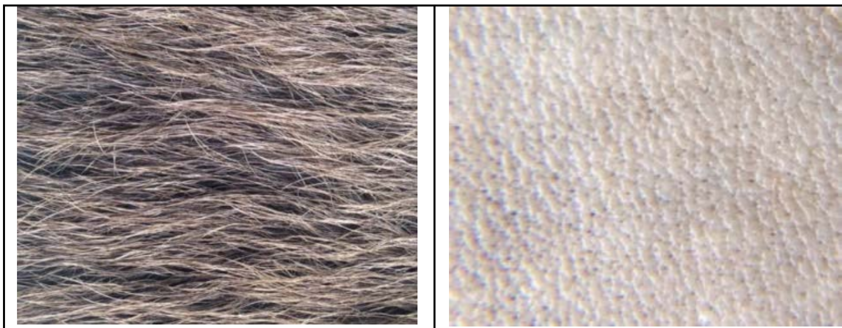
The objective of the present work is to determine the coefficient of friction between the cow skin and iron steel, as effect increased pressure and angular velocity at different normal loads on the coefficient of friction, study the mechanical properties of cow skin and observe increased creep area.

2. Experimental part

In this part of the study, pieces of cow skin with dimensions (25 x 25 x 4) mm taken from 1-year-old male were prepared for the experimental. The pieces were washing with pure water and then shaving in one direction to remove all hairs on the surface as shown in Fig. 1. In order to sure that the mechanical and chemical properties of the skin stable, the skin after each experimental froze keep at temperature -18 0C. One TAL201 load cell with maximum measuring range 100 Newton was used to measure the friction. An iron steel ball with diameter 12.75

mm used as a tip to apply the normal force in the experimental as shown in Fig. 2.

One amplifier-HX711 was used to convert the analog signal to digital signal. One Arduino maga-2560 used to transport the digital signal to the personal computer. All these devices installed on machine four balls to measure the friction of the skin as shown in Fig. 3, this test bed was adapted and developed by the authors. The results were obtained at load operating conditions (2.5, 5, 7.5 and 10 Newton), and angular velocity (1.99, 5.34, 8.19 and 11.73 rev/s).



Before clean	After clean

Figure 1: A sample of skin process

Figure 2: Iron steel ball tip

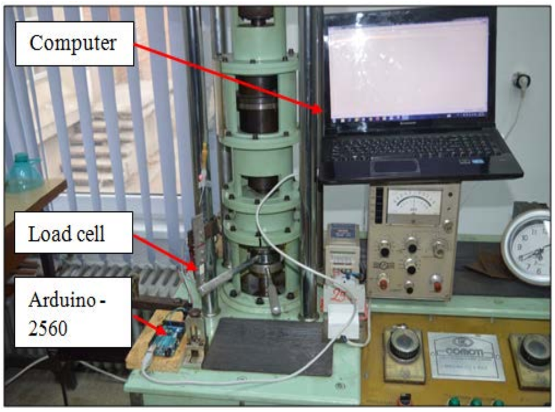


Figure 3: Adapting device to measure the kinetic friction

3. Results and discussion

Hence, The results are collected under the operating conditions and divided into two parts: the first part of results is related to the investigation of the most important mechanical properties of cow skin such as coefficient of friction as a function of many parameters including probe angular velocity, normal force, and pressure. The second parts of results related to measuring the trace diameter and depth of cow skin in terms of time and load.

3.1. Coefficient of friction

Fig. 4 presents the coefficient of friction (μ) as a function of angular velocity at different load (2.5, 5, 7.5 and 10 N). Generally, the coefficient of friction considers one of the important mechanical properties of the metal. It is clear from this picture that the coefficient of friction increased when the angular velocity increased. The maximum coefficient of friction was registered 0.057 at load 2.5 N, which is 4.34 %, 30.1 %, and 39.9 % higher than that produced, by the loads 5, 7.5 and 10 N, respectively at angular speed 11.73 rad/sec. These results are similar to those reported by [2].

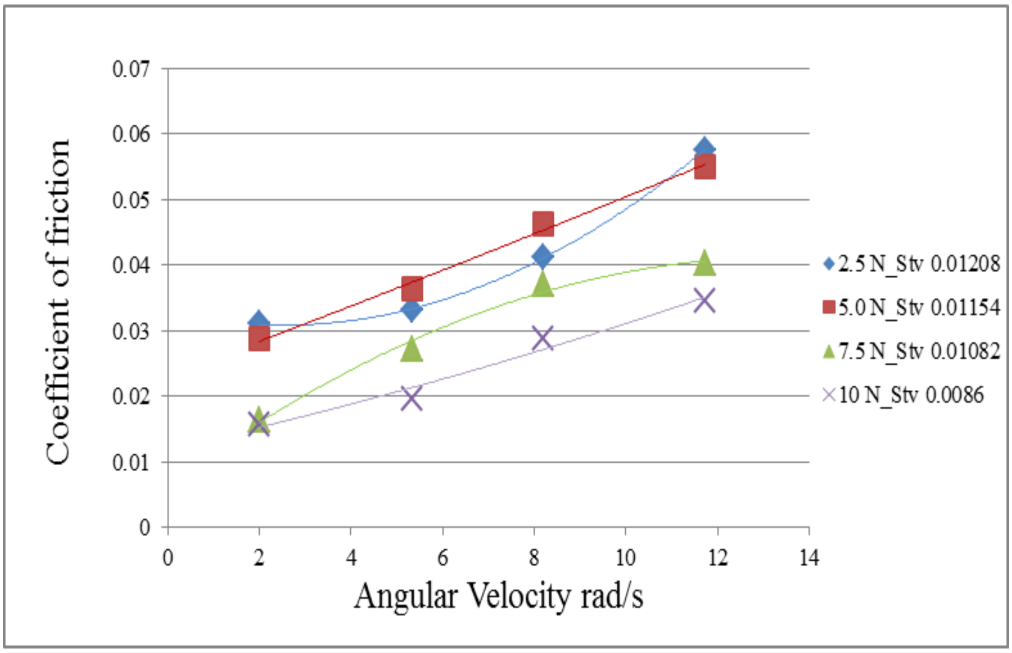


Figure 4: The coefficient of friction vs. angular velocity

Fig. 5. present the coefficient of friction as a function of applied pressure on the skin at different angular speed (v1=1.99, v2=5.34, v3=8.19 and v4=11.73 rev/s) as well as the standard deviation for every case.

It has been shown from the figure, the coefficient of friction decreased when the pressure increased at all angular velocity. When the pressure increased, the normal force applied on test skin increased resulting in a reduction in coefficient of friction.

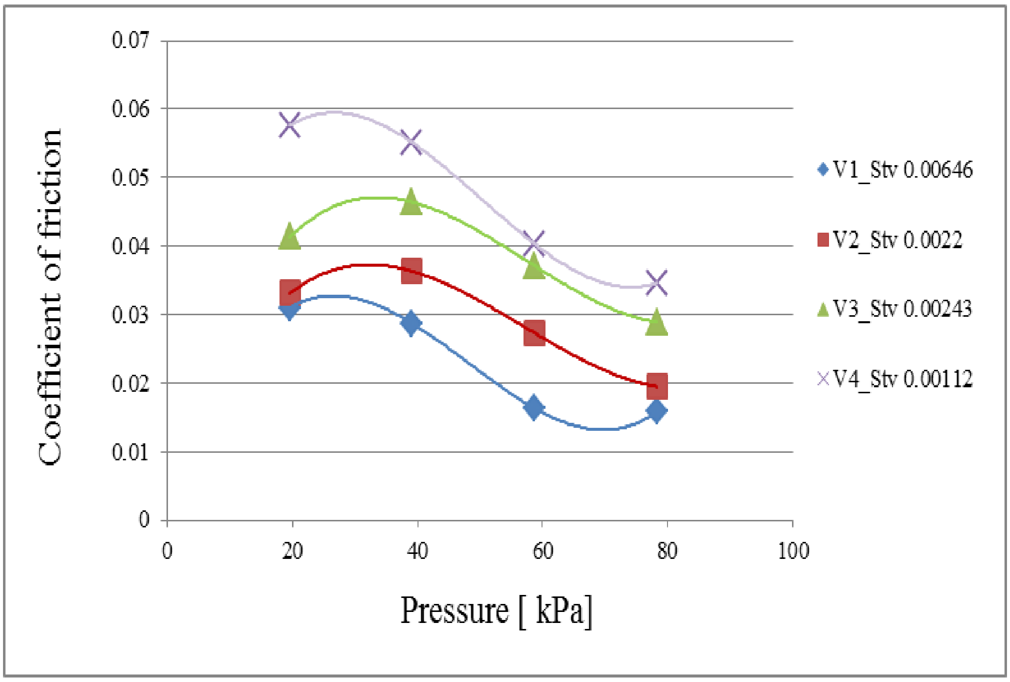


Figure 5: The coefficient of friction vs. pressure

The contact area trace was measured by using a simple ruler to determine the trace diameter immediately after the experiment as shown in Fig. 6., and Fig. 7 shows plots coefficient of friction predictions for different speeds and variety pressures of cow skin. The continuum curve in Fig.7 is obtained by fitting experimental results. It is observed that the parameter pressure (p) velocity (ω) (p ω) have not influence about the friction coefficient. The parameter (μ p ω) will be analyzed in the future as a fatigue and parameter of fatigue and deterioration of skin.

The contact pressures were measured via known the applied normal force and contact area values. The coefficient of friction was higher at pressure 78 MPa and speed 11.73 rad/sec than the other operating conditions. The increase in coefficient of friction may be due to increases in the normal force applied to test skin.

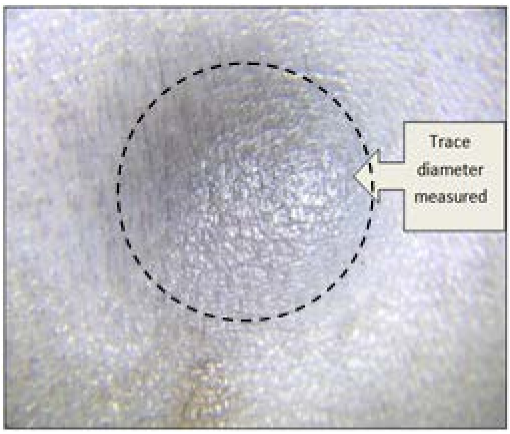


Figure 6: Trace diameter measure

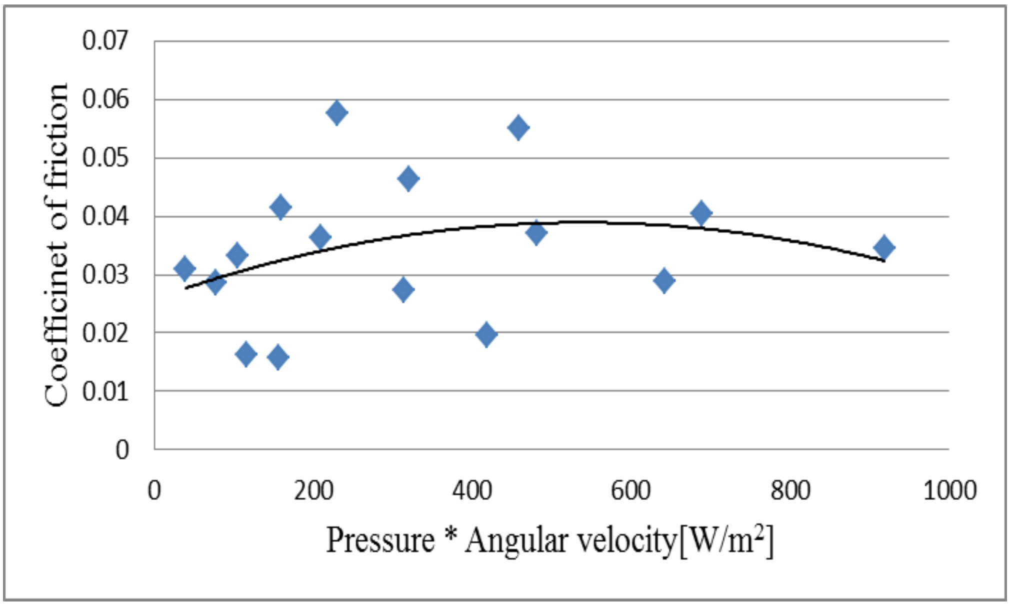


Figure 7: The coefficient of friction vs. pressure time angular velocity

3.2. Contact area

The contact area is the area measured between the tip of indenter and the skin. The variation of contact area respect to the applied pressure on cow skins for the different sample with maximum and minimum contact area value shown in Fig. 8. Generally, the contact area increased when the applied pressure increased. The max deviation was 24.7% registered at applied 12000 Pa, whereas the minimum value was recorded 9.14% at pressure 16000 Pa. The explanation of these variations is due to the mechanical and physical properties of cow skin.

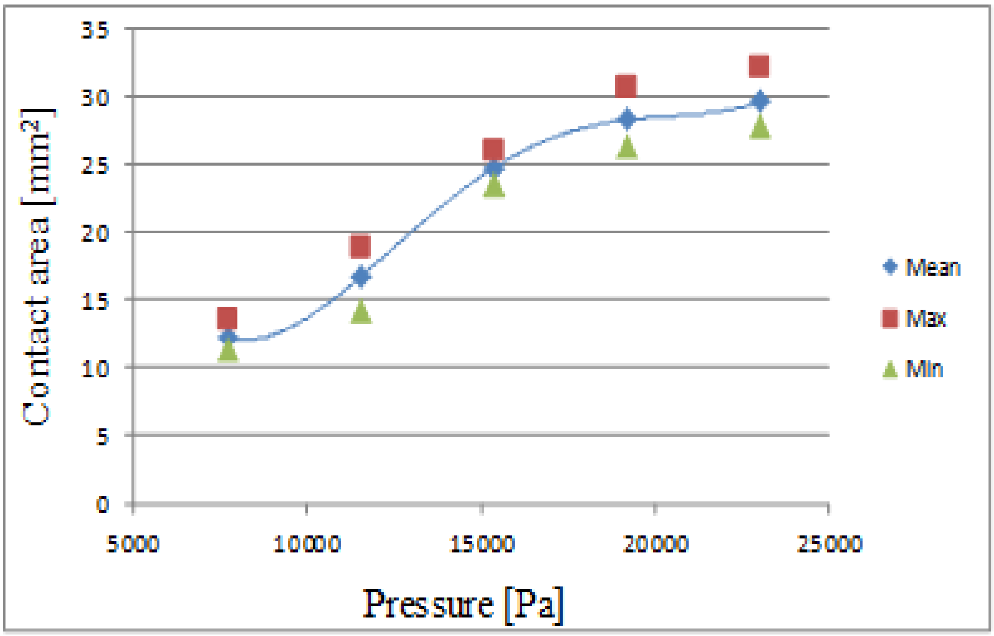


Figure 8: Contact area vs. applied pressure.

3.3. Indenter depth

The variation of trace depth respect to applied pressure for three cow skin samples denoted by h_1, h_2, and h_3 is shown in Fig. 9. As shown in this figure, at same operating condition there are some deviations in depth between these samples. The explanation of this behavior could be due to the fact that the cow skin is considered to be a viscoelastic material. It is clear from this figure, that the depth is increased by increasing the pressure. in the same manner, mean of the three samples denoted by h_m are represented by a hidden line shown in the figure.

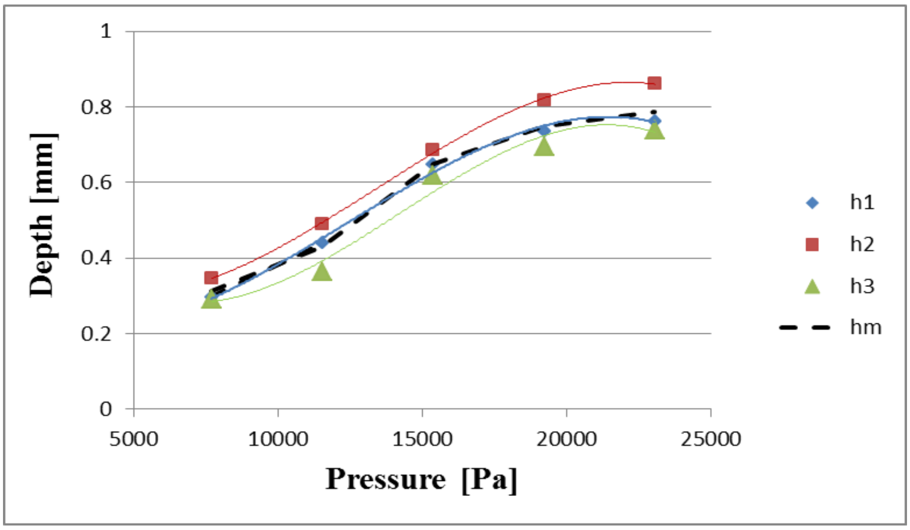


Figure 9: Tip depth vs. applied pressure

4. Conclusions

The coefficient of friction for cow skin was measured at different pressure and different angular velocity. The cow skin has mechanical properties such as viscoelastic and non-linear are similar to the human skin. Based on the obtained results, the following conclusions can be made:

- The coefficient of friction was increased when the angular velocity increased in the studied range (2-12 rad/s).
- The coefficient of friction was decreased when the pressure increased (20-80 kPa).
- Contact area increased when the applied pressure increased.
- The tip of indenter depth was higher when the pressure was higher.

Acknowledgements

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5. Recommendations

The authors recommend studying mechanical properties for cow skin such as viscoelastic and comparing it with the properties of human skin. Also, study the use of cow skin as an inner layer in prosthetic socket from the inside.

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